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(54) **SYSTEM FOR PARALLELLY PROCESSING
IMAGE LINES FROM MULTIPLE IMAGE
SENSORS**

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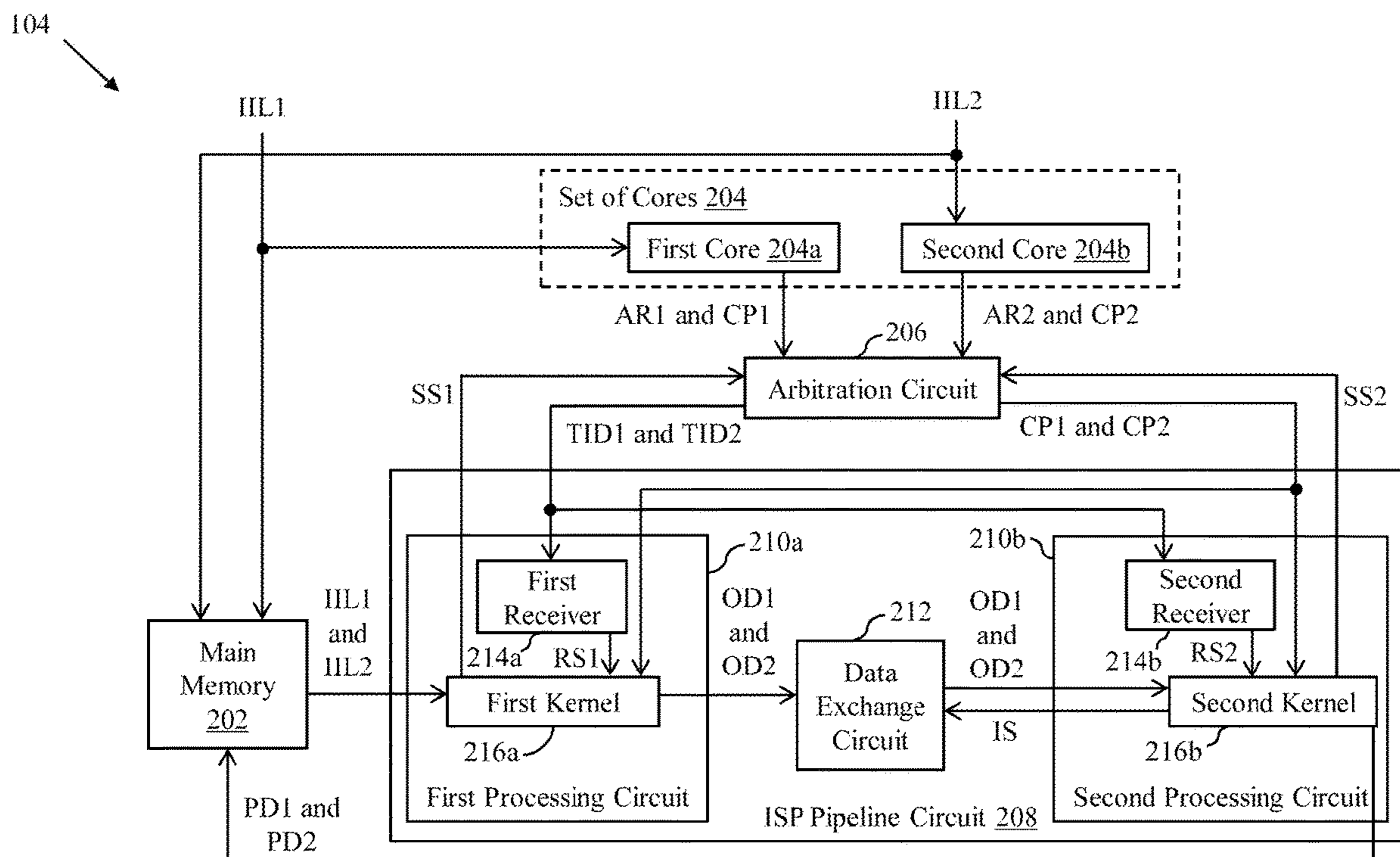
(57) **ABSTRACT**

A system-on-chip (SoC) includes first and second processing circuits and a data exchange circuit such that the first processing circuit is configured to process image lines based on corresponding sets of processing attributes. The first processing circuit is further configured to continuously receive and process the image lines one after the other to generate corresponding output data, and the second processing circuit is configured to continuously receive by way of the data exchange circuit, the generated output data for processing the generated output data. The data exchange circuit is thus configured to control data flow between the first processing circuit and the second processing circuit such that the first processing circuit and the second processing circuit parallelly process corresponding data associated with same or different image lines.

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CPC H04N 5/2258; H04N 5/23227; H04N
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9/28; G06F 9/38; G06F 9/3885-3897;
G06F 13/1615

See application file for complete search history.

20 Claims, 9 Drawing Sheets



100 

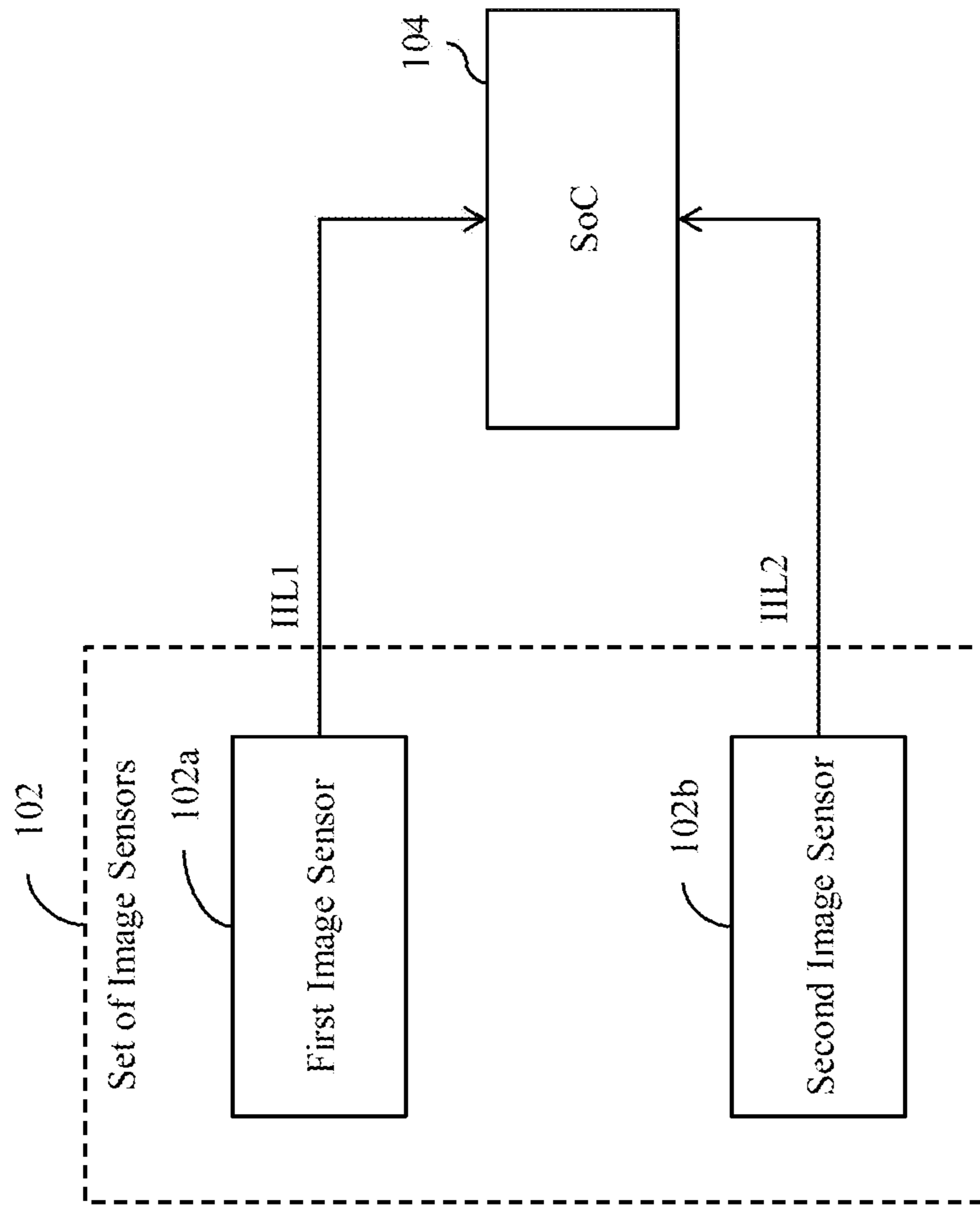


FIG. 1

104 ↗

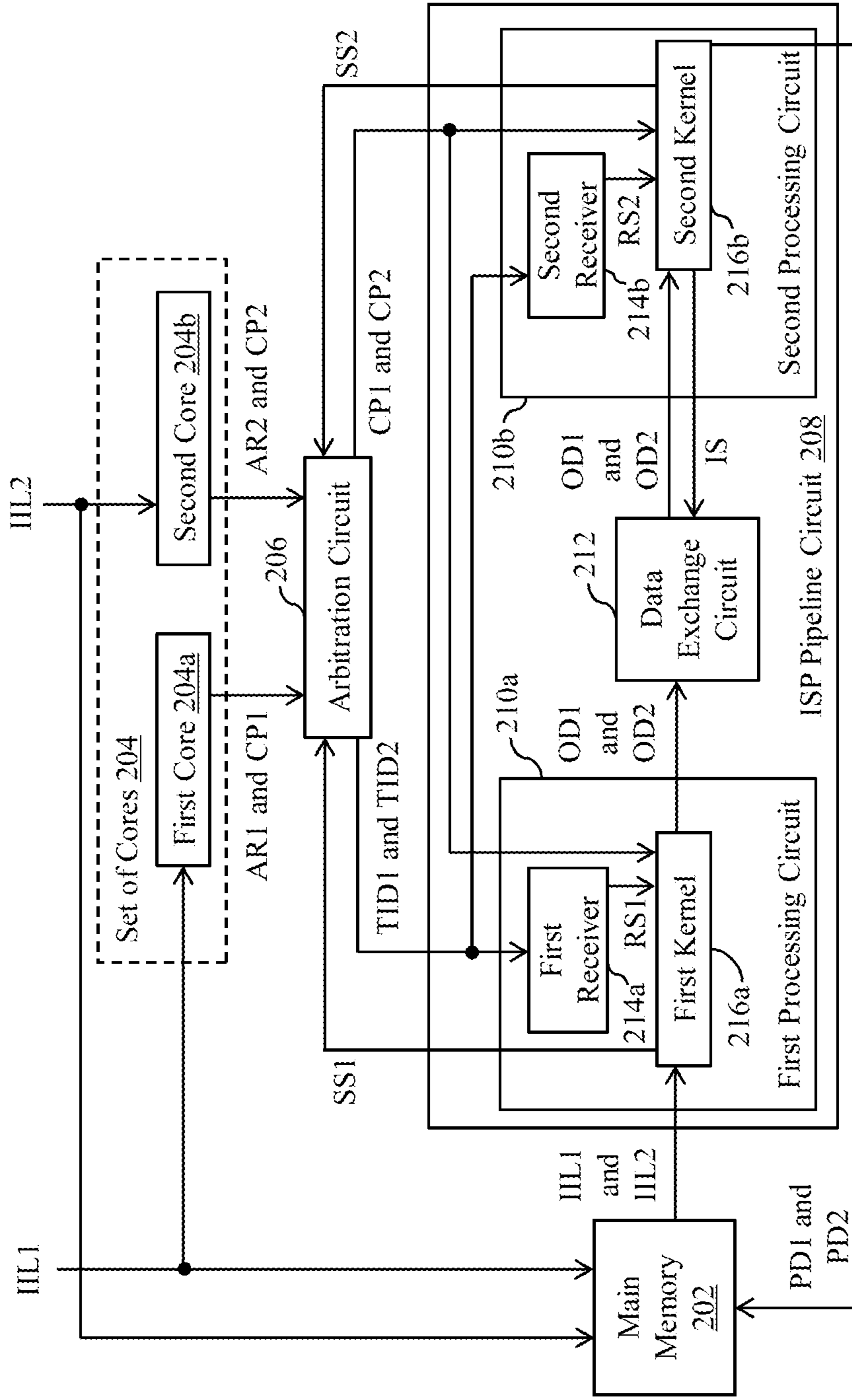


FIG. 2

206 ↗

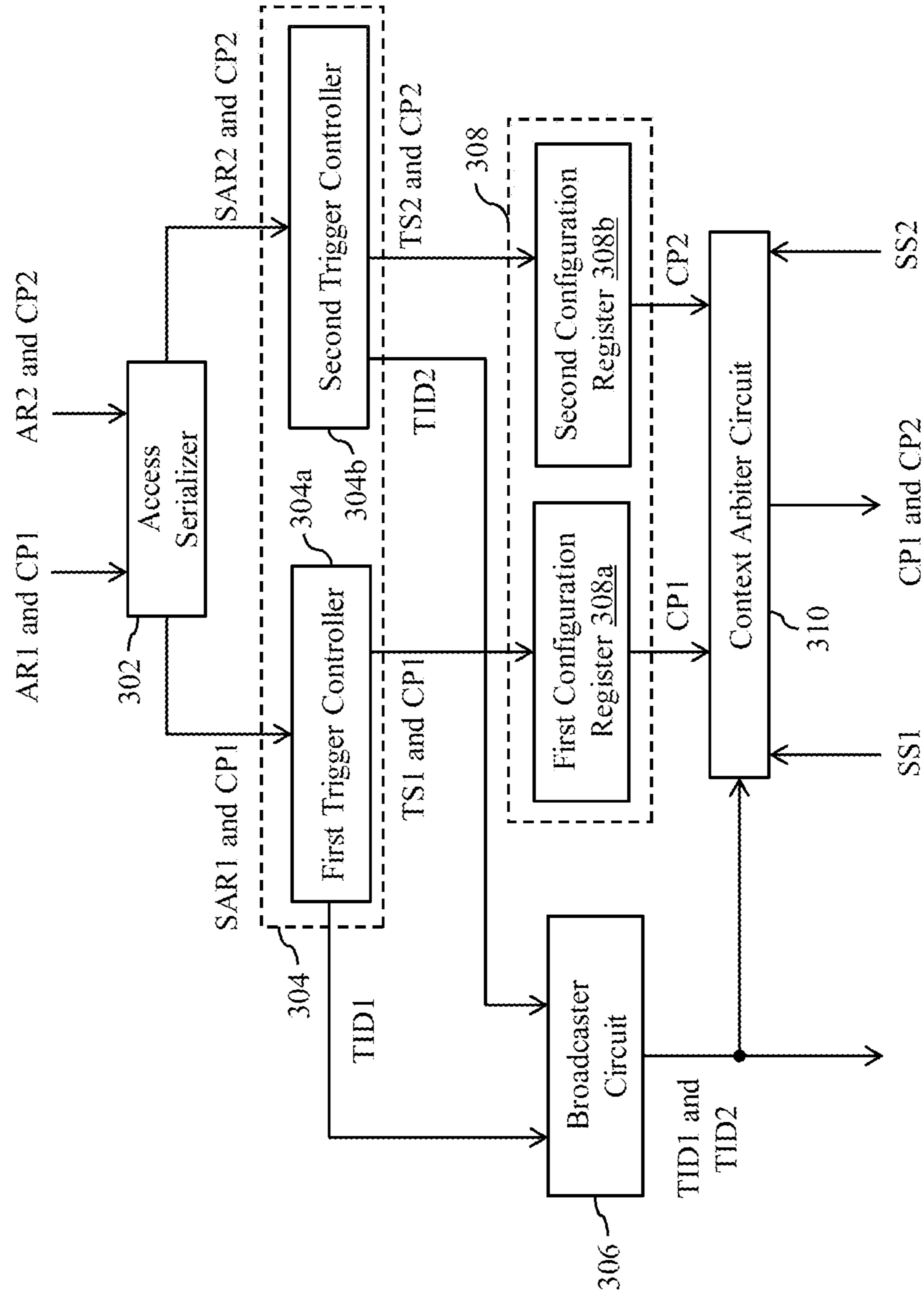


FIG. 3

400 ↗

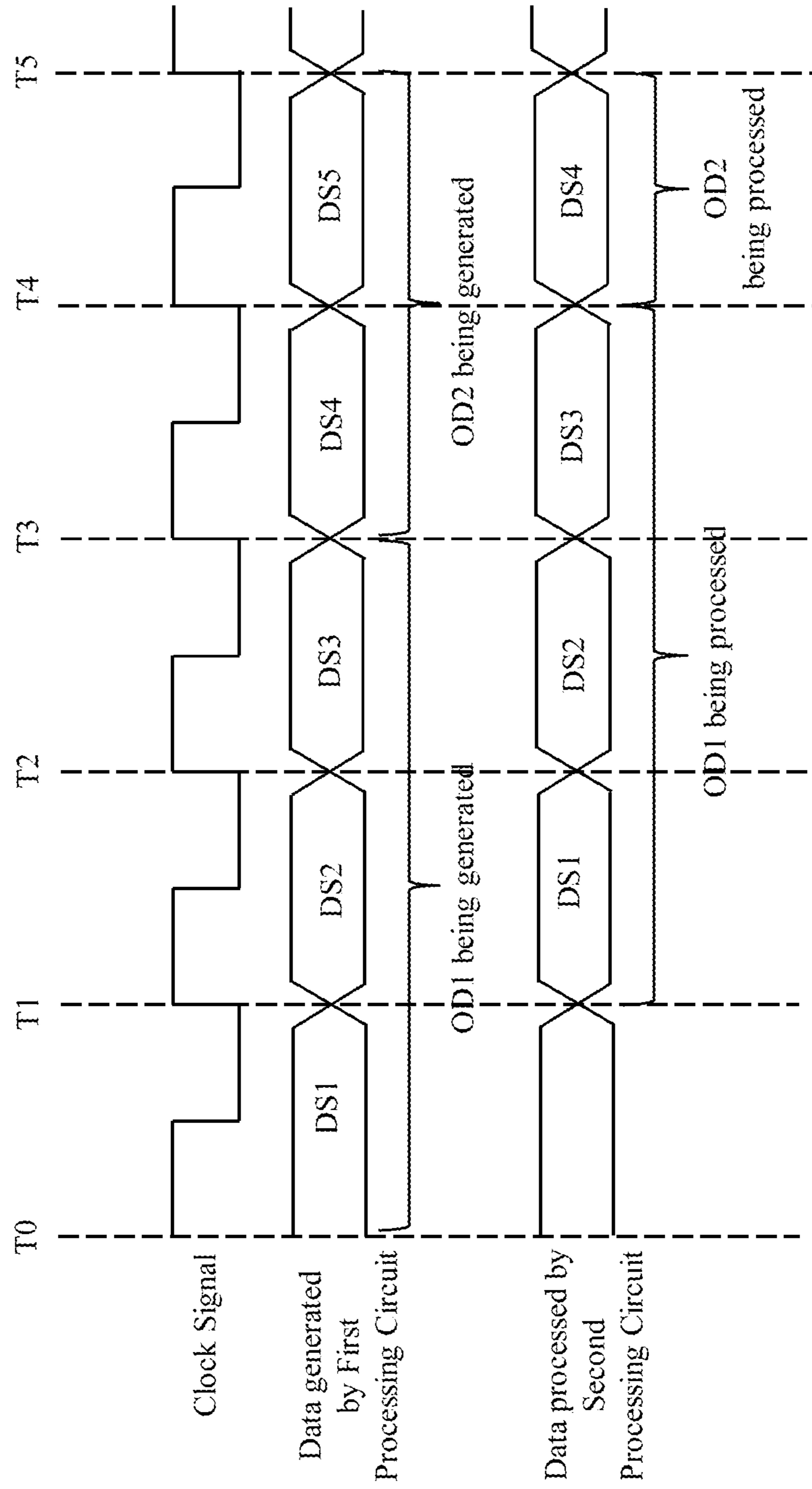


FIG. 4

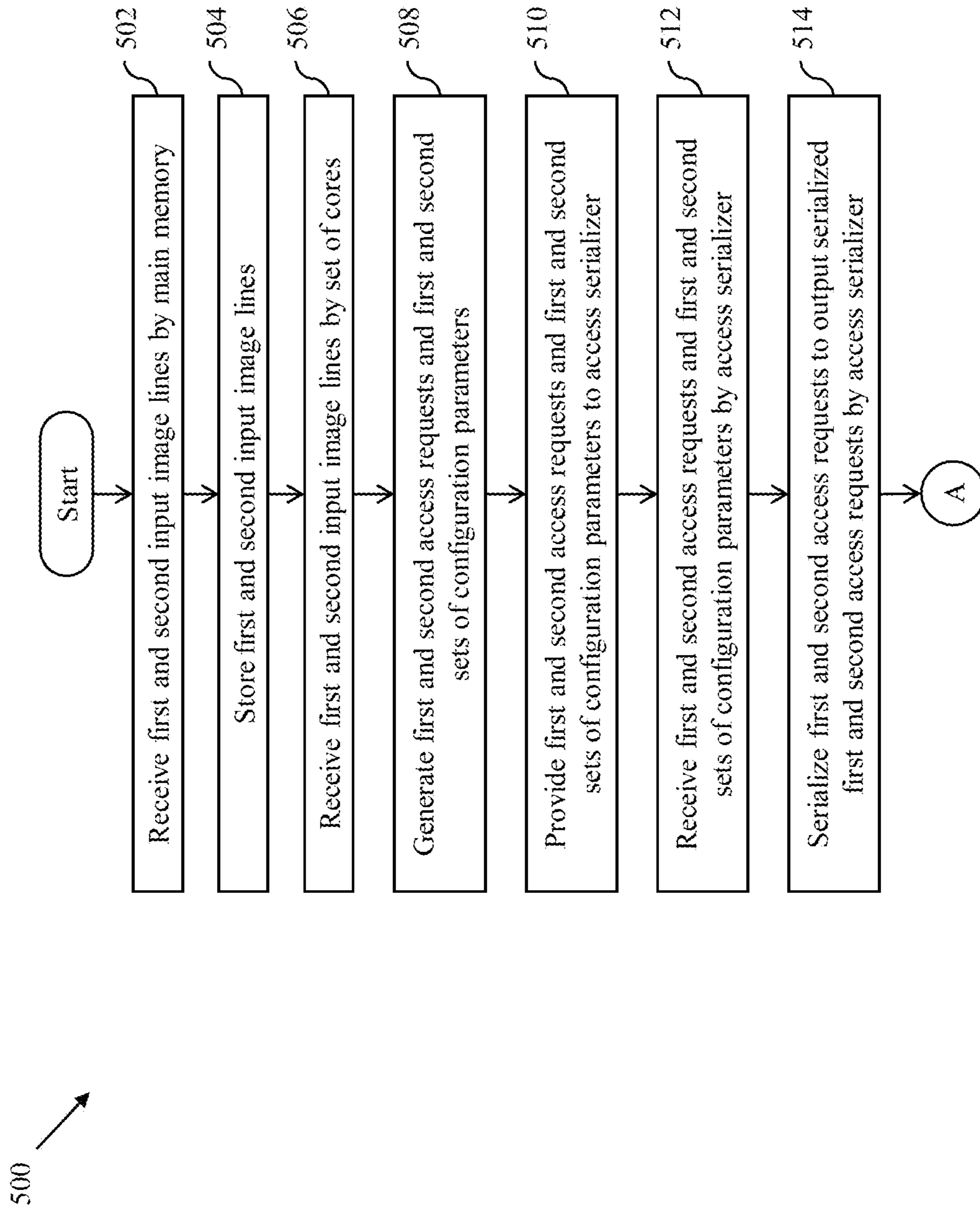


FIG. 5A

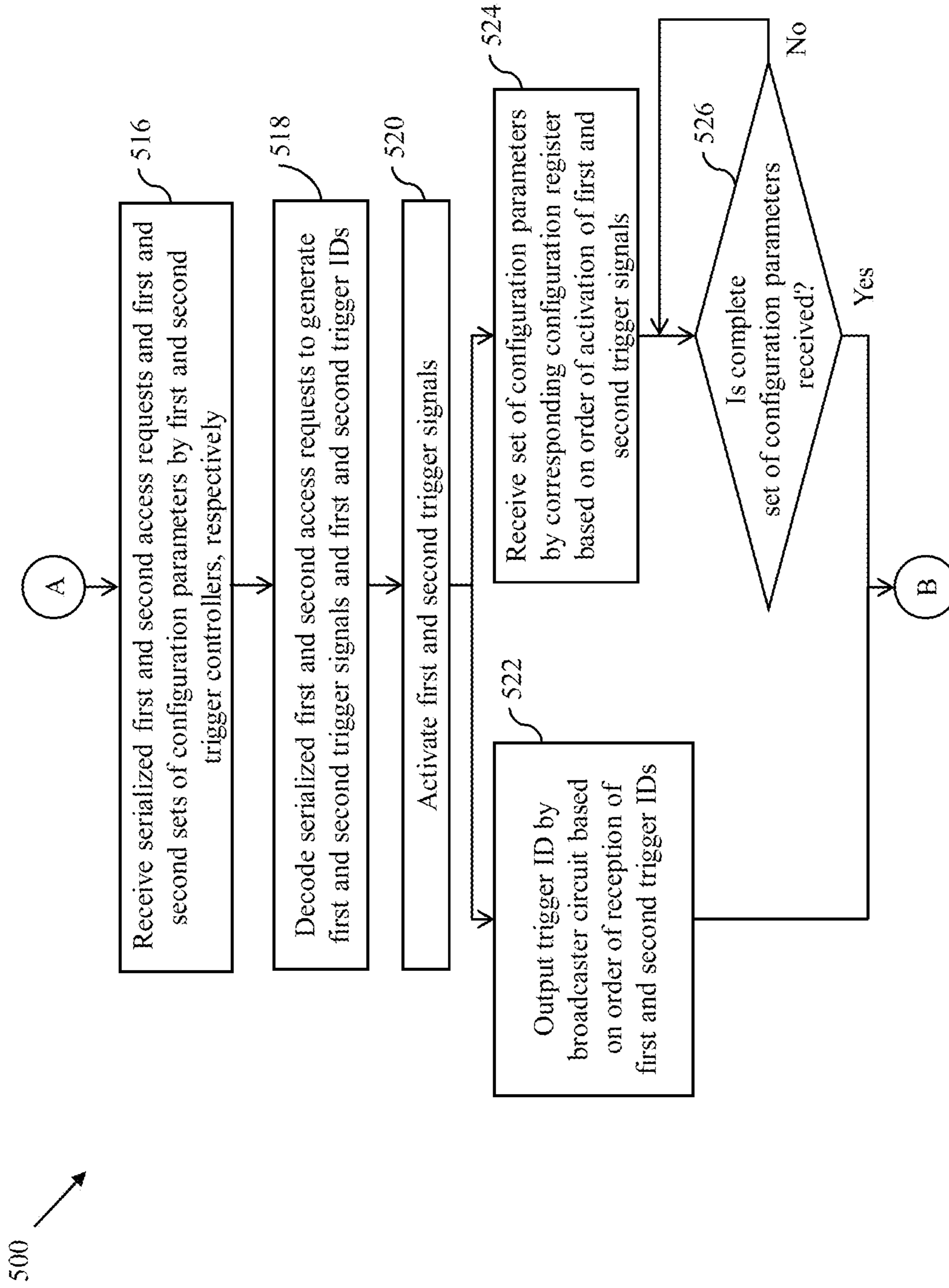


FIG. 5B

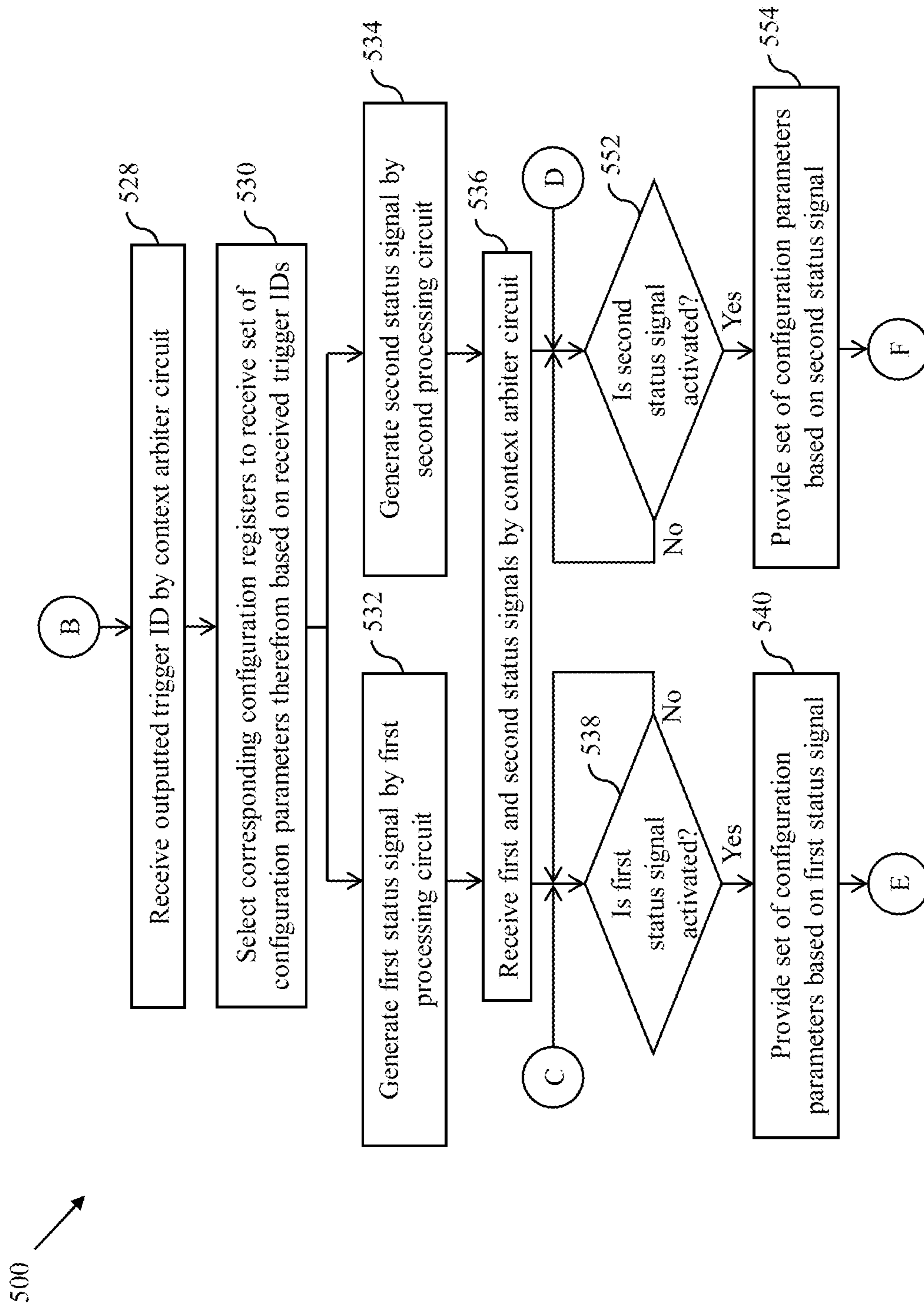


FIG. 5C

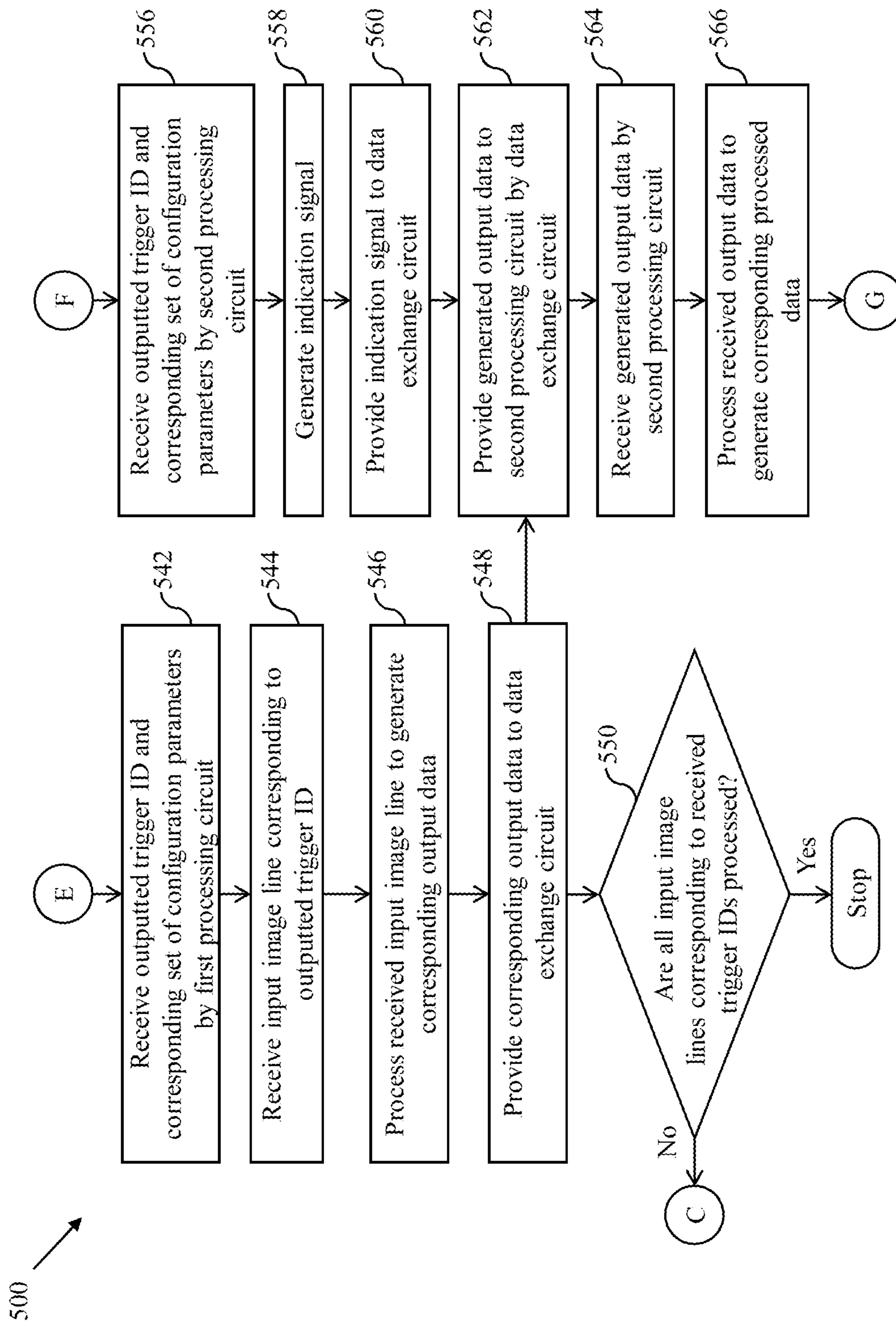


FIG. 5D

500 ↗

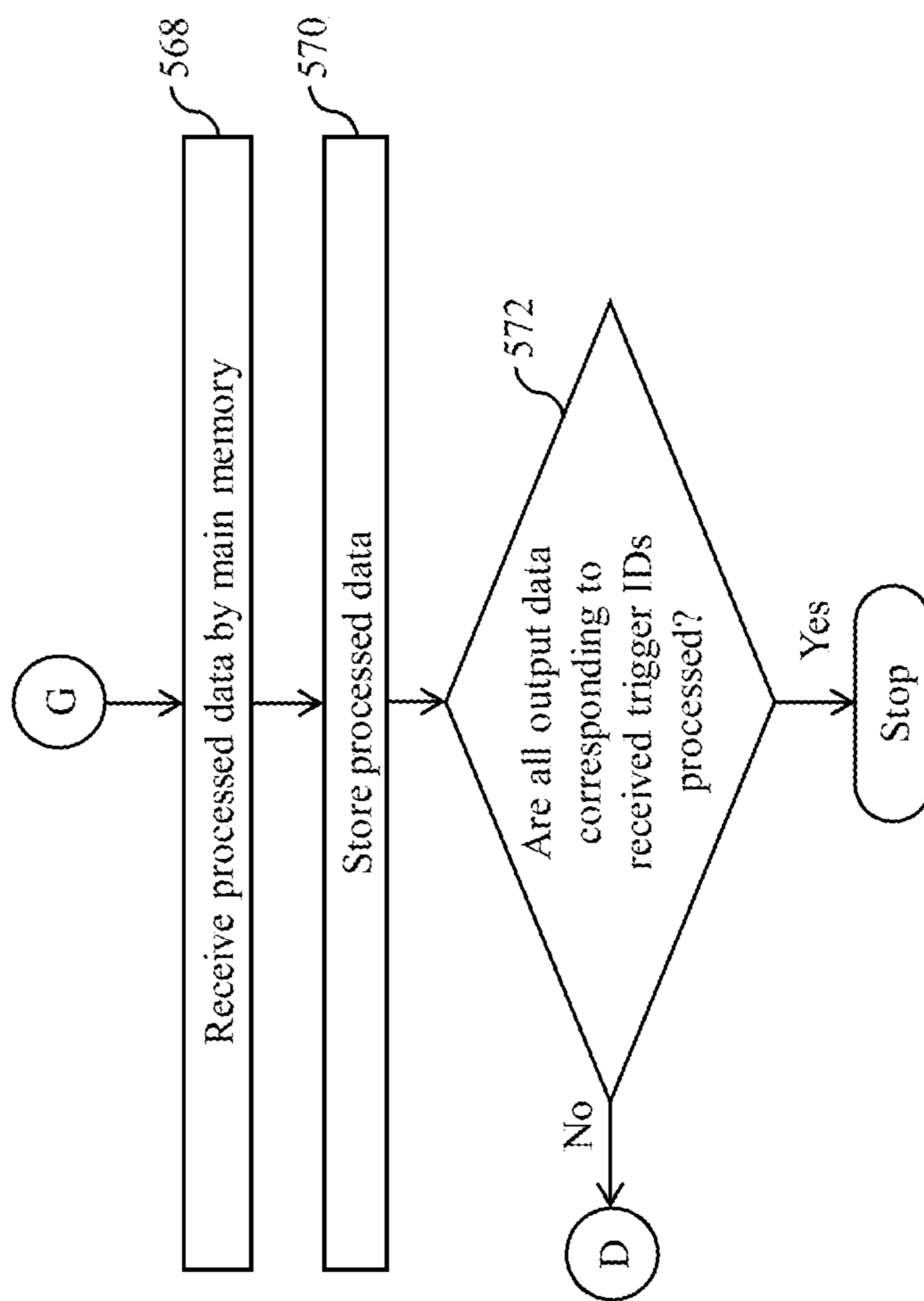


FIG. 5E

SYSTEM FOR PARALLELLY PROCESSING IMAGE LINES FROM MULTIPLE IMAGE SENSORS

BACKGROUND

The present disclosure relates generally to image processing, and, more particularly, to a system for parallelly processing multiple image lines on a system-on-chip (SoC).

An SoC typically receives and processes image lines that are associated with a single image or multiple images. The image lines may be captured by various image sensors that have high resolution and high frame rate. Typically for on-the-fly (OTF) processing of such image lines, the captured image lines are stitched to generate a large image stream. However, the stitching of the image lines on the SoC causes latency in the OTF processing. Further, the quality of such a large image stream is degraded due to different exposure values and resolutions of the image sensors. To overcome the problem associated with the stitching of the image lines, the captured image lines are processed by an SoC one at a time. However, the image sensors generate the image lines at a high speed which leads to a processing overhead and a delay in processing of the image lines as the SoC is capable of processing only one image line at a time. Thus, there is a need for a technical solution that overcomes the aforementioned problems.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description of the preferred embodiments of the present disclosure will be better understood when read in conjunction with the appended drawings. The present disclosure is illustrated by way of example, and not limited by the accompanying figures, in which like references indicate similar elements.

FIG. 1 is a schematic block diagram of a system for parallelly processing multiple image lines in accordance with an embodiment of the present disclosure;

FIG. 2 is a schematic block diagram of a system-on-chip (SoC) of the system of FIG. 1 in accordance with an embodiment of the present disclosure;

FIG. 3 is a schematic block diagram of an arbitration circuit of the SoC of FIG. 2 in accordance with an embodiment of the present disclosure;

FIG. 4 is a timing diagram that illustrates an operation of first and second processing circuits of the SoC of FIG. 2 in accordance with an embodiment of the present disclosure; and

FIGS. 5A-5E, collectively, represent a flow chart that illustrates a method for parallelly processing multiple image lines by the SoC of FIG. 2 in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

The detailed description of the appended drawings is intended as a description of the currently preferred embodiments of the present disclosure, and is not intended to represent the only form in which the present disclosure may be practiced. It is to be understood that the same or equivalent functions may be accomplished by different embodiments that are intended to be encompassed within the spirit and scope of the present disclosure.

In one embodiment, the present disclosure provides a system-on-chip (SoC) that includes first and second processing circuits and a data exchange circuit. The first pro-

cessing circuit is configured to receive and process a first image line based on a first set of processing attributes to generate first output data, and a second image line based on a second set of processing attributes to generate second output data. Further, the second image line is processed after the first image line is processed. The data exchange circuit is coupled between the first processing circuit and the second processing circuit. The data exchange circuit is configured to provide the first and second output data from the first processing circuit to the second processing circuit based on an availability of the second processing circuit to process the first and second output data, respectively. The second processing circuit is configured to parallelly process the first output data when the first processing circuit processes the second image line.

In another embodiment, the present disclosure provides a method for processing a plurality of image lines. The method includes processing, by a first processing circuit of an SoC, a first image line of the plurality of image lines based on a first set of processing attributes to generate first output data, and a second image line of the plurality of image lines based on a second set of processing attributes to generate second output data. Further, the second image line is processed after the first image line is processed. The method further includes providing, by a data exchange circuit of the SoC, the first and second output data from the first processing circuit to a second processing circuit of the SoC based on an availability of the second processing circuit to process the first and second output data, respectively. The method further includes processing, by the second processing circuit, the first output data parallelly when the second image line is being processed by the first processing circuit.

Various embodiments of the present disclosure provide an SoC that includes first and second processing circuits and a data exchange circuit. The first processing circuit is configured to process each image line based on respective processing attributes, such that a subsequent image line is processed after the current image line is processed. The image lines are processed to generate corresponding output data. The data exchange circuit is configured to provide the generated output data from the first processing circuit to the second processing circuit based on an availability of the second processing circuit to process the generated output data one at a time. The second processing circuit is configured to parallelly process the output data that is generated based on the current image line when the first processing circuit processes the subsequent image line.

As the image lines are processed based on a set of processing attributes such as trigger identifiers (that indicate an order of processing the image lines) and configuration parameters (that indicate image features of the image lines), the quality of the processed image lines remains unaffected due to different exposure values, different resolutions, and different frame rates of multiple image sensors that capture the image lines. Further, the first and second processing circuits process the image lines one after the other and refrain from stitching of the image lines. Thus, the latency for on-the-fly processing of each image line is reduced as compared to the latency incurred by conventional techniques that implement stitching of the image lines. Additionally, the first processing circuit and the second processing circuit are able to process different image lines parallelly, thereby reducing a processing overhead and a delay in processing of the multiple image lines as compared to conventional systems that were unable to process different image lines parallelly.

Referring now to FIG. 1, a schematic block diagram of a system **100** for parallelly processing multiple image lines (hereinafter referred to as “input image lines”), in accordance with an embodiment of the present disclosure is shown. Each input image line represents an array of pixel data of a corresponding input image. The system **100** may be utilized in an automotive application such as an advanced driver alert system (ADAS), a consumer application such as a home security system, or an industrial application such as an industrial robotic system. The system **100** includes multiple image sensors **102** of which first and second image sensors **102a** and **102b** are shown. The system **100** further includes a system-on-chip (SoC) **104**.

The first and second image sensors **102a** and **102b** capture first and second input images, respectively. In an example, the first and second image sensors **102a** and **102b** capture and output first and second input image lines IIL1 and IIL2 that are associated with the first and second input images, respectively. In presently preferred embodiment, the first and second image sensors **102a** and **102b** have different resolutions, different frame rates, and different exposure values. In another embodiment, the first and second image sensors **102a** and **102b** have same resolutions, same frame rates, and same exposure values. Examples of the first and second image sensors **102a** and **102b** include a bayer image sensor, a monochrome image sensor, an infrared bayer image sensor, and the like. It will be apparent to those of skill in the art that the scope of the system **100** is not limited to two image sensors, and may include any number of image sensors without deviating from the scope of the disclosure.

The SoC **104** is coupled with external image sensors, i.e., the first and second image sensors **102a** and **102b**, for receiving the first and second input image lines IIL1 and IIL2, respectively. The SoC **104** processes the first and second input image lines IIL1 and IIL2 based on first and second sets of processing attributes, to generate first and second processed data (shown later in FIG. 2), respectively. The first and second sets of processing attributes are associated with the processing of the first and second input image lines IIL1 and IIL2 captured by the first and second image sensors **102a** and **102b**, respectively.

Referring now to FIG. 2, a schematic block diagram of the SoC **104**, in accordance with an embodiment of the present disclosure is shown. The SoC **104** includes a main memory **202**, a set of cores **204** of which first and second cores **204a** and **204b** are shown, an arbitration circuit **206**, and an image signal processing (ISP) pipeline circuit **208**.

The main memory **202** is coupled with the first and second image sensors **102a** and **102b**, and is configured to receive the first and second input image lines IIL1 and IIL2. In one example, the main memory **202** is a random-access memory (RAM), such as a video RAM. The main memory **202** is further configured to store the received first and second input image lines IIL1 and IIL2.

The set of cores **204** (i.e., the first and second cores **204a** and **204b**) is coupled with the first and second image sensors **102a** and **102b**, and is configured to receive the first and second input image lines IIL1 and IIL2 from the first and second image sensors **102a** and **102b**, respectively. The first and second cores **204a** and **204b** are further configured to generate first and second access requests AR1 and AR2 and first and second sets of configuration parameters CP1 and CP2 that are associated with the processing of the first and second input image lines IIL1 and IIL2, respectively. Each of the first and second sets of configuration parameters CP1 and CP2 includes at least one of image features such as a color, a gain, a region of interest, a resolution, a frame

number, a line number and the like, of a corresponding input image line, such as the first or second input image line IIL1 or IIL2, captured by an image sensor, such as the first or second image sensor **102a** or **102b**. It will be apparent to those of skill in the art that the scope of the SoC **104** is not limited to two cores, and may include any number of cores without deviating from the scope of the disclosure. It will further be apparent to those of skill in the art that even though in the current embodiment, the first and second cores **204a** and **204b** are coupled with the first and second image sensors **102a** and **102b**, and generate the first and second access requests AR1 and AR2, respectively, in other embodiments, a single core, such as the first core **204a**, is coupled with both the first and second image sensors **102a** and **102b**, and generates the first and second access requests AR1 and AR2, respectively.

The set of cores **204** is coupled with the arbitration circuit **206**, and is further configured to provide the first and second access requests AR1 and AR2 and the first and second sets of configuration parameters CP1 and CP2, respectively, to the arbitration circuit **206**. The arbitration circuit **206** is thus configured to receive the first and second access requests AR1 and AR2 and the first and second sets of configuration parameters CP1 and CP2, respectively. The arbitration circuit **206** is further configured to generate first and second trigger identifiers (IDs) TID1 and TID2 based on the first and second access requests AR1 and AR2, respectively, and output the first and second trigger IDs TID1 and TID2 and the first and second sets of configuration parameters CP1 and CP2, respectively. The first and second trigger IDs TID1 and TID2 are indicative of an order of triggering the processing of the first and second input image lines IIL1 and IIL2, respectively. The first set of processing attributes includes the first trigger ID TID1 and the first set of configuration parameters CP1, and the second set of processing attributes includes the second trigger ID TID2 and the second set of configuration parameters CP2. The structure and working of the arbitration circuit **206** is explained in detail in FIG. 3.

The ISP pipeline circuit **208** is coupled with the arbitration circuit **206**. The ISP pipeline circuit **208** includes multiple processing circuits of which a first processing circuit **210a** and a second processing circuit **210b** are shown, for processing the first and second input image lines IIL1 and IIL2, respectively. Each processing circuit executes an image processing function. Examples of the image processing functions include image decompression, color temperature detection, white balance correction, dynamic range adjustment, vignetting effect correction, and the like. In an embodiment, the first processing circuit **210a** and the second processing circuit **210b** execute the image processing functions such as image decompression and vignetting effect correction, respectively. It will be apparent to a person skilled in the art that a number of processing circuits in the ISP pipeline circuit **208** is based on a number of image processing functions to be executed by the ISP pipeline circuit **208**. Thus, to execute the image processing functions such as color temperature detection, white balance correction, and dynamic range adjustment, the ISP pipeline circuit **208** includes three additional processing circuits (not shown). The ISP pipeline circuit **208** further includes a data exchange circuit **212** that is coupled between two processing circuits, i.e., the first processing circuit **210a** and the second processing circuit **210b**. Thus, it will be further apparent to a person skilled in the art that a number of data exchange circuits in the ISP pipeline circuit **208** is based on the number of processing circuits in the ISP pipeline circuit **208**.

The first processing circuit **210a** is coupled with the main memory **202** and the arbitration circuit **206**, and is configured to receive the first and second input image lines **IIL1** and **IIL2** from the main memory **202**, and receive the first and second trigger IDs **TID1** and **TID2** and the first and second sets of configuration parameters **CP1** and **CP2** from the arbitration circuit **206**, respectively. The first processing circuit **210a** is further configured to process the first and second input image lines **IIL1** and **IIL2** to generate first and second output data **OD1** and **OD2** based on the first and second trigger IDs **TID1** and **TID2** and the first and second sets of configuration parameters **CP1** and **CP2**, i.e., the first and second sets of processing attributes, respectively. The second input image line **IIL2** is processed after the first input image line **IIL1** is processed. The first processing circuit **210a** is further coupled with the data exchange circuit **212**, and is further configured to provide the first and second output data **OD1** and **OD2** to the data exchange circuit **212**.

The first processing circuit **210a** includes a first receiver **214a** and a first kernel **216a**. The first receiver **214a** is coupled with the arbitration circuit **206**, and is configured to receive the first and second trigger IDs **TID1** and **TID2**. In one embodiment, the first receiver **214a** stores the first and second trigger IDs **TID1** and **TID2** in an order of reception of the first and second trigger IDs **TID1** and **TID2** in an internal memory (not shown) of the first receiver **214a**. The first receiver **214a** is further configured to generate a first reception signal **RS1** that is indicative of a reception of at least one of the first and second trigger IDs **TID1** and **TID2** by the first receiver **214a**.

The first kernel **216a** is an image processing kernel that performs an image processing function such as image decompression, image correction, or the like. The first kernel **216a** is coupled with the main memory **202**, the first receiver **214a**, and the arbitration circuit **206**. The first kernel **216a** is configured to receive at least one of the first and second input image lines **IIL1** and **IIL2** at a time from the main memory **202**. The first kernel **216a** is further configured to receive the first reception signal **RS1** from the first receiver **214a**, generate a first status signal **SS1** that indicates an availability of the first processing circuit **210a** to receive at least one of the first and second sets of configuration parameters **CP1** and **CP2**, i.e., at least one of the first and second sets of processing attributes, at a time, and provide the first status signal **SS1** to the arbitration circuit **206**. Based on the first reception signal **RS1**, the first kernel **216a** is triggered to process at a time, at least one of the first and second input image lines **IIL1** and **IIL2** to generate at least one of the first and second output data **OD1** and **OD2**, respectively. The first kernel **216a** is further configured to activate the first status signal **SS1** for receiving at least one of the first and second sets of configuration parameters **CP1** and **CP2**, and deactivate the first status signal **SS1** when the first kernel **216a** is processing at least one of the first and second input image lines **IIL1** and **IIL2**.

The second processing circuit **210b** is coupled with the arbitration circuit **206**, and is configured to receive the first and second trigger IDs **TID1** and **TID2** and the first and second sets of configuration parameters **CP1** and **CP2**, respectively. The second processing circuit **210b** is further configured to receive the first and second output data **OD1** and **OD2** and process the first and second output data **OD1** and **OD2** to generate the first and second processed data **PD1** and **PD2** based on the first and second trigger IDs **TID1** and **TID2** and the first and second sets of configuration parameters **CP1** and **CP2**, i.e., the first and second sets of processing attributes, respectively. The second output data **OD2**

is processed after the first output data **OD1** is processed. The second processing circuit **210b** receives the second output data **OD2** and the second set of configuration parameters **CP2** when the second processing circuit **210b** has generated the first processed data **PD1**.

The second processing circuit **210b** includes a second receiver **214b** and a second kernel **216b**. The second receiver **214b** is structurally and functionally similar to the first receiver **214a**. The second receiver **214b** is coupled with the arbitration circuit **206**, and is configured to receive the first and second trigger IDs **TID1** and **TID2** and generate a second reception signal **RS2** that is indicative of a reception of at least one of the first and second trigger IDs **TID1** and **TID2** by the second receiver **214b**.

The second kernel **216b** is structurally and functionally similar to the first kernel **216a**. The second kernel **216b** is coupled with the data exchange circuit **212** and the second receiver **214b**, and is configured to receive one of the first and second output data **OD1** and **OD2** at a time from the data exchange circuit **212**, and receive the second reception signal **RS2** from the second receiver **214b**. The second kernel **216b** is further coupled with the arbitration circuit **206**, and is further configured to generate a second status signal **SS2** that indicates an availability of the second kernel **216b** to receive at least one of the first and second sets of configuration parameters **CP1** and **CP2**, i.e., at least one of the first and second sets of processing attributes, at a time, and provide the second status signal **SS2** to the arbitration circuit **206**. Based on the second reception signal **RS2**, the second kernel **216b** is further configured to process at a time, at least one of the first and second output data **OD1** and **OD2** to generate at least one of the first and second processed data **PD1** and **PD2**, respectively. The second kernel **216b** is further configured to activate the second status signal **SS2** for receiving at least one of the first and second sets of configuration parameters **CP1** and **CP2**, and deactivate the second status signal **SS2** when the second kernel **216b** is processing at least one of the first and second output data **OD1** and **OD2**. The second processing circuit **210b** is further configured to generate an indication signal **IS** and provide the indication signal **IS** to the data exchange circuit **212** to indicate an availability of the second processing circuit **210b** for processing at least one of the first and second output data **OD1** and **OD2**. The indication signal **IS** is indicative of a completion of a processing of the received output data, such as the first output data **OD1**, by the second processing circuit **210b**, and the second processing circuit **210b** being available to receive subsequent output data, such as the second output data **OD2**.

The data exchange circuit **212** is coupled between the first processing circuit **210a** and the second processing circuit **210b** to control a flow of data between the first processing circuit **210a** and the second processing circuit **210b**. The data exchange circuit **212** is configured to receive the indication signal **IS** and provide the output data (such as the first output data **OD1**) received from the first processing circuit **210a** to the second processing circuit **210b** when the second processing circuit **210b** is available to receive the output data, such that the second processing circuit **210b** and the first processing circuit **210a** parallelly process the received output data and the subsequent input image line (such as the second input image line **IIL2**), respectively. The second processing circuit **210b** is available to receive the subsequent output data when the second processing circuit **210b** has generated the processed data (such as the first processed data **PD1**) that is associated with the previously received output data (i.e., the first output data **OD1**). In one

embodiment, the data exchange circuit **212** provides at least one of the first and second output data **OD1** and **OD2** from the first processing circuit **210a** to the second processing circuit **210b** based on an availability of the second processing circuit **210b** to process the first and second output data **OD1** and **OD2**, respectively, when the indication signal **IS** is activated.

The data exchange circuit **212** includes a first-in-first-out (FIFO) memory (not shown) that receives and stores the first and second output data **OD1** and **OD2**. In one example, when the data exchange circuit **212** receives the first output data **OD1** from the first processing circuit **210a**, and the second processing circuit **210b** is unavailable to receive and process the first output data **OD1**, the first output data **OD1** is queued in the FIFO memory. Further, the queued first output data **OD1** is provided to the second processing circuit **210b** when the second processing circuit **210b** is available for receiving and processing the first output data **OD1**. Similarly, the second output data **OD2** is queued when the data exchange circuit **212** receives the second output data **OD2** and the second processing circuit **210b** is unavailable to receive and process the second output data **OD2**.

The main memory **202** is further coupled with the second processing circuit **210b**, and is configured to receive the first and second processed data **PD1** and **PD2** and store the first and second processed data **PD1** and **PD2**, respectively.

Referring now to FIG. 3, a schematic block diagram of the arbitration circuit **206**, in accordance with an embodiment of the present disclosure is shown. The arbitration circuit **206** includes an access serializer **302**, multiple trigger controllers **304** of which first and second trigger controllers **304a** and **304b** are shown, a broadcaster circuit **306**, multiple configuration registers **308** of which first and second configuration registers **308a** and **308b** are shown, and a context arbiter circuit **310**.

The access serializer **302** is coupled with the first and second cores **204a** and **204b**, and is configured to receive the first and second access requests **AR1** and **AR2**, and the first and second sets of configuration parameters **CP1** and **CP2**, respectively. The access serializer **302** is further configured to serialize the first and second access requests **AR1** and **AR2** to output the serialized first and second access requests **SAR1** and **SAR2**, respectively. In an embodiment, the access serializer **302** executes a scheduling algorithm such as a round-robin scheduling algorithm, to serialize the first and second access requests **AR1** and **AR2** and output the serialized first and second access requests **SAR1** and **SAR2** one after the other. In an example, when the first access request **AR1** is received before the second access request **AR2**, the access serializer **302** outputs the serialized first access request **SAR1** before the serialized second access request **SAR2**. In another example, when the first and second access requests **AR1** and **AR2** are received simultaneously at the same time instant or during a single clock cycle, the access serializer **302** outputs the serialized first and second access requests **SAR1** and **SAR2** one after the other (i.e., outputs the serialized first access request **SAR1** or the serialized second access request **SAR2**). The access serializer **302** is further configured to output the first and second sets of configuration parameters **CP1** and **CP2** along with the serialized first and second access requests **SAR1** and **SAR2**, respectively.

The first and second trigger controllers **304a** and **304b** are coupled with the access serializer **302**, and are configured to receive the serialized first and second access requests **SAR1** and **SAR2** and the first and second sets of configuration parameters **CP1** and **CP2** from the first and second trigger

controllers **304a** and **304b**, respectively. The first and second trigger controllers **304a** and **304b** are further configured to decode the serialized first and second access requests **SAR1** and **SAR2** to generate first and second trigger signals **TS1** and **TS2** and the first and second trigger IDs **TID1** and **TID2**, respectively. The first and second trigger controllers **304a** and **304b** are further configured to activate the first and second trigger signals **TS1** and **TS2**, when the first and second trigger controllers **304a** and **304b** decode the serialized first and second access requests **SAR1** and **SAR2**, respectively.

It will be apparent to those of skill in the art that the scope of the arbitration circuit **206** is not limited to two trigger controllers, and may include any number of trigger controllers based on a number of image sensors without deviating from the scope of the disclosure.

The first and second configuration registers **308a** and **308b** are coupled with the first and second trigger controllers **304a** and **304b**. The first and second configuration registers **308a** and **308b** are configured to receive the first and second trigger signals **TS1** and **TS2** and the first and second sets of configuration parameters **CP1** and **CP2** from the first and second trigger controllers **304a** and **304b**, respectively. When the first and second trigger signals **TS1** and **TS2** are activated, the first and second configuration registers **308a** and **308b** receive the first and second sets of configuration parameters **CP1** and **CP2** from the first and second trigger controllers **304a** and **304b**, respectively.

It will be apparent to those of skill in the art that the scope of the arbitration circuit **206** is not limited to two configuration registers, and may include any number of configuration registers based on a number of image sensors without deviating from the scope of the disclosure.

The broadcaster circuit **306** is coupled with the first and second trigger controllers **304a** and **304b**. The broadcaster circuit **306** is configured to receive the first and second trigger IDs **TID1** and **TID2** from the first and second trigger controllers **304a** and **304b**, respectively, and output the first and second trigger IDs **TID1** and **TID2** based on an order of reception of the first and second trigger IDs **TID1** and **TID2**, respectively.

The context arbiter circuit **310** is coupled with the broadcaster circuit **306**, and is configured to receive the first and second trigger IDs **TID1** and **TID2** and the first and second status signals **SS1** and **SS2**. The context arbiter circuit **310** is further configured to select the first and second configuration registers **308a** and **308b** based on the first and second trigger IDs **TID1** and **TID2** for receiving the first and second sets of configuration parameters **CP1** and **CP2** therefrom. The context arbiter circuit **310** is further configured to provide at a time, at least one of the first and second sets of configuration parameters **CP1** and **CP2** to the first processing circuit **210a** when the first status signal **SS1** is activated, and at least one of the first and second sets of configuration parameters **CP1** and **CP2** to the second processing circuit **210b** when the second status signal **SS2** is activated.

Referring now to FIG. 4, a timing diagram **400** illustrating an operation of the first processing circuit **210a** and the second processing circuit **210b** in accordance with an embodiment of the present disclosure is shown. In the embodiment, the SoC **104** includes a clock generator circuit (not shown) that generates a clock signal for controlling the operation of the first processing circuit **210a** and the second processing circuit **210b**. In one example, the first output data **OD1** includes first through third data segments **DS1-DS3** and the second output data **OD2** includes fourth and fifth data segments **DS4** and **DS5**.

During time duration T0-T1, the first processing circuit **210a** is available for processing the first input image line IIL1. Thus, the first processing circuit **210a** receives and processes the first input image line IIL1 to generate the first data segment DS1. The first processing circuit **210a** provides the first data segment DS1 to the data exchange circuit **212**.

At time instant T1, the data exchange circuit **212** determines that the second processing circuit **210b** is available for receiving and processing the first data segment DS1 based on the indication signal IS. The data exchange circuit **212** thus provides the first data segment DS1 to the second processing circuit **210b**.

During time duration T1-T2, the first processing circuit **210a** continues to process the first input image line IIL1 to generate the second data segment DS2. The first processing circuit **210a** provides the second data segment DS2 to the data exchange circuit **212**. As the data exchange circuit **212** determines based on the indication signal IS that the second processing circuit **210b** is unavailable to receive and process the second data segment DS2 since the second processing circuit **210b** is processing the first data segment DS1, the second data segment DS2 is queued in the FIFO memory.

At time instant T2, the second processing circuit **210b** completes the processing of the first data segment DS1. Thus, the indication signal IS indicates that the second processing circuit **210b** is available for receiving and processing the second data segment DS2. The data exchange circuit **212** hence provides the second data segment DS2 to the second processing circuit **210b**.

During time duration T2-T3, the first processing circuit **210a** continues to process the first input image line IIL1 to generate the third data segment DS3 and the second processing circuit **210b** processes the second data segment DS2. The first processing circuit **210a** provides the third data segment DS3 to the data exchange circuit **212**. As the second processing circuit **210b** is processing the second data segment DS2, the indication signal IS indicates unavailability of the second processing circuit **210b** to receive and process the third data segment DS3. The third data segment DS3 is thus queued in the FIFO memory.

At time instant T3, the first processing circuit **210a** completes the processing of the first input image line IIL1 to generate the first output data OD1 completely and activates the first status signal SS1. The second processing circuit **210b** completes the processing of the second data segment DS2. Thus, the indication signal IS indicates that the second processing circuit **210b** is available for receiving and processing the third data segment DS3. The data exchange circuit **212** hence provides the third data segment DS3 to the second processing circuit **210b**.

During time duration T3-T4, the first processing circuit **210a** receives and processes the second input image line IIL2 to generate the fourth data segment DS4 and the second processing circuit **210b** processes the third data segment DS3. The first processing circuit **210a** provides the fourth data segment DS4 to the data exchange circuit **212**. As the second processing circuit **210b** is processing the third data segment DS3, the indication signal IS indicates unavailability of the second processing circuit **210b** to receive and process the fourth data segment DS4. The fourth data segment DS4 is thus queued in the FIFO memory.

At time instance T4, the second processing circuit **210b** completes the processing of the first output data OD1 to generate the first processed data PD1 completely. Further, the second processing circuit **210b** activates the second status signal SS2 when the first processed data PD1 is completely generated. The indication signal IS indicates that

the second processing circuit **210b** is available for receiving and processing the fourth data segment DS4. The data exchange circuit **212** hence provides the fourth data segment DS4 to the second processing circuit **210b**.

During time duration T4-T5, the first processing circuit **210a** continues to process the second input image line IIL2 to generate the fifth data segment DS5 and the second processing circuit **210b** processes the fourth data segment DS4. The first processing circuit **210a** provides the fifth data segment DS5 to the data exchange circuit **212**. As the second processing circuit **210b** is processing the fourth data segment DS4, the indication signal IS indicates unavailability of the second processing circuit **210b** to receive and process the fifth data segment DS5. The fifth data segment DS5 is thus queued in the FIFO memory. The fifth data segment DS5 is provided to the second processing circuit **210b** when the indication signal IS indicates availability of the second processing circuit **210b** to receive and process the fifth data segment DS5.

From the time duration T2-T3, the first processing circuit **210a** and the second processing circuit **210b** continuously generate and process data segments corresponding to the same input image line (such as the first input image line IIL1) or different input image lines (such as the first and second input image lines IIL1 and IIL2). Thus, the system **100** is able to process different input image lines simultaneously and does not wait to process the second input image line IIL2 until the first input image line IIL1 is processed completely, thereby enabling the system **100** to operate at a high speed.

Referring now to FIGS. 5A-5E, a flow chart **500** illustrating a method for parallelly processing multiple input image lines by the SoC **104**, in accordance with an embodiment of the present disclosure is shown.

At step **502**, the main memory **202** receives the first and second input image lines IIL1 and IIL2 from the first and second image sensors **102a** and **102b**, respectively. The first and second image sensors **102a** and **102b** have different resolutions and different frame rates. At step **504**, the main memory **202** stores the first and second input image lines IIL1 and IIL2. At step **506**, the set of cores **204**, i.e., the first and second cores **204a** and **204b**, receives the first and second input image lines IIL1 and IIL2 from the first and second image sensors **102a** and **102b**, respectively.

At step **508**, the first and second cores **204a** and **204b** generate the first and second access requests AR1 and AR2 and the first and second sets of configuration parameters CP1 and CP2, respectively. The first and second access requests AR1 and AR2 and the first and second sets of configuration parameters CP1 and CP2 are generated based on an order of reception of the first and second input image lines IIL1 and IIL2, respectively. At step **510**, the first and second cores **204a** and **204b** provide the first and second access requests AR1 and AR2 and the first and second sets of configuration parameters CP1 and CP2 to the access serializer **302**, respectively.

At step **512**, the access serializer **302** receives the first and second access requests AR1 and AR2 and the first and second sets of configuration parameters CP1 and CP2. At step **514**, the access serializer **302** serializes the first and second access requests AR1 and AR2, by executing the scheduling algorithm, to output the serialized first and second access requests SAR1 and SAR2 one after the other. At step **516**, the first and second trigger controllers **304a** and **304b** receive the serialized first and second access requests SAR1 and SAR2 and the first and second sets of configuration parameters CP1 and CP2, respectively.

At step 518, the first and second trigger controllers 304a and 304b decode the serialized first and second access requests SAR1 and SAR2 to generate the first and second trigger signals TS1 and TS2 and the first and second trigger IDs TID1 and TID2, respectively. At step 520, the first and second trigger controllers 304a and 304b activate the first and second trigger signals TS1 and TS2, when the first and second trigger controllers 304a and 304b decode the serialized first and second access requests SAR1 and SAR2, respectively. The first and second trigger signals TS1 and TS2 are activated based on an order of generation of the first and second trigger signals TS1 and TS2, respectively. After step 520, steps 522 and 524 are executed simultaneously.

At step 522, the broadcaster circuit 306 outputs a trigger ID, such as one of the first and second trigger IDs TID1 and TID2, based on the order of reception of the first and second trigger IDs TID1 and TID2 by the broadcaster circuit 306 from the first and second trigger controllers 304a and 304b, respectively. For the sake of ongoing discussion and without deviating from the scope of the disclosure, it is assumed that the first trigger ID TID1 is outputted before the second trigger ID TID2.

At step 524, configuration registers, such as the first and second configuration registers 308a and 308b, receive corresponding sets of configuration parameters, such as the first and second sets of configuration parameters CP1 and CP2, based on an order of activation of the first and second trigger signals TS1 and TS2. At step 526, the first and second configuration registers 308a and 308b determine whether the complete first and second sets of configuration parameters CP1 and CP2 are received by the first and second configuration registers 308a and 308b. If at step 526, the first and second configuration registers 308a and 308b determine that the complete first and second sets of configuration parameters CP1 and CP2 are not received, the first and second configuration registers 308a and 308b wait for the complete first and second sets of configuration parameters CP1 and CP2 to be received. If at step 526, the first and second configuration registers 308a and 308b determine that the complete first and second sets of configuration parameters CP1 and CP2 are received, step 528 is executed. Step 528 is executed after the execution of the steps 522 and 526.

At step 528, the context arbiter circuit 310 receives the outputted trigger IDs, such as the first and second trigger IDs TID1 and TID2, from the broadcaster circuit 306. At step 530, the context arbiter circuit 310 selects corresponding configuration registers, such as the first and second configuration registers 308a and 308b, for receiving the first and second sets of configuration parameters CP1 and CP2 therefrom based on the received trigger IDs. After step 530, steps 532 and 534 are executed simultaneously. At step 532, the first processing circuit 210a generates the first status signal SS1. At step 534, the second processing circuit 210b generates the second status signal SS2. After executing the steps 532 and 534, step 536 is executed.

At step 536, the context arbiter circuit 310 receives the first and second status signals SS1 and SS2 from the first processing circuit 210a and the second processing circuit 210b, respectively. After executing the step 536, steps 538-550 and 552-572 are executed simultaneously. At step 538, the context arbiter circuit 310 determines whether the first status signal SS1 is activated. If at step 538, the context arbiter circuit 310 determines that the first status signal SS1 is not activated (i.e., deactivated), the context arbiter circuit 310 waits for the first status signal SS1 to be activated. If at step 538, the context arbiter circuit 310 determines that the first status signal SS1 is activated, step 540 is executed.

At step 540, the context arbiter circuit 310 provides a set of configuration parameters, such as the first set of configuration parameters CP1, to the first processing circuit 210a based on the first status signal SS1. At step 542, the first processing circuit 210a receives the outputted trigger ID, such as the first trigger ID TID1, and the corresponding set of configuration parameters, such as the first set of configuration parameters CP1, from the context arbiter circuit 310.

At step 544, the first processing circuit 210a receives an input image line, such as the first input image line IIL1, corresponding to the outputted trigger ID, i.e., the first trigger ID TID1, from the main memory 202. At step 546, based on the first trigger ID TID1 and the first set of configuration parameters CP1, i.e., the first set of processing attributes, the first processing circuit 210a processes the received input image line, i.e., the first input image line IIL1, to generate corresponding output data, i.e., the first output data OD1. The first output data OD1 is generated by generating corresponding data segments as explained in FIG. 4. Further, the first status signal SS1 is deactivated when the first processing circuit 210a is processing the first input image line IIL1. At step 548, the first processing circuit 210a provides the corresponding output data, i.e., the first output data OD1, to the data exchange circuit 212 and re-activates the first status signal SS1. At step 550, the first processing circuit 210a determines whether all input image lines, such as the first and second input image lines IIL1 and IIL2, corresponding to the received trigger IDs, such as the first and second trigger IDs TID1 and TID2, are processed by the first processing circuit 210a. Since at step 550, the first processing circuit 210a determines that all input image lines corresponding to the received trigger IDs are not processed by the first processing circuit 210a, the steps 538-550 are executed continuously until all input image lines corresponding to the received trigger IDs are processed by the first processing circuit 210a. Thus, the second input image line IIL2 is processed. After executing the steps 538-548 for processing the second input image line IIL2, at step 550, the first processing circuit 210a determines that all the input image lines corresponding to the received trigger IDs are processed. Thus, the first processing circuit 210a completes the generation of all the output data based on the received input image lines.

At step 552, the context arbiter circuit 310 determines whether the second status signal SS2 is activated. If at step 552, the context arbiter circuit 310 determines that the second status signal SS2 is deactivated, the context arbiter circuit 310 waits for the second status signal SS2 to be activated. If at step 552, the context arbiter circuit 310 determines that the second status signal SS2 is activated, step 554 is executed.

At step 554, the context arbiter circuit 310 provides a set of configuration parameters, such as the first set of configuration parameters CP1, to the second processing circuit 210b based on the second status signal SS2. At step 556, the second processing circuit 210b receives the outputted trigger ID, such as the first trigger ID TID1, and the corresponding set of configuration parameters, such as the first set of configuration parameters CP1, from the context arbiter circuit 310. At step 558, the second processing circuit 210b generates the indication signal IS. At step 560, the second processing circuit 210b provides the indication signal IS to the data exchange circuit 212. After steps 548 and 560, step 562 is executed.

At step 562, the data exchange circuit 212 provides the generated output data, such as the first output data OD1, to the second processing circuit 210b based on the indication

signal IS. At step 564, the second processing circuit 210b receives the generated output data, such as the first output data OD1, from the data exchange circuit 212. At step 566, based on the first trigger ID TID1 and the first set of configuration parameters CP1, i.e., the first set of processing attributes, the second processing circuit 210b processes the received output data, i.e., the first output data OD1, to generate corresponding processed data, i.e., the first processed data PD1. The second processing circuit 210b processes the received output data, i.e., the first output data OD1, parallelly when a subsequent image line, i.e., the second input image line IIL2, is being processed by the first processing circuit 210a. The first output data OD1 is processed by way of processing the data segments of the first output data OD1 as explained in FIG. 4. Further, during the processing of the first output data OD1, the second processing circuit 210b deactivates the second status signal SS2.

At step 568, the main memory 202 receives the processed data, i.e., the first processed data PD1 from the second processing circuit 210b. At step 570, the main memory 202 stores the first processed data PD1. At step 572, the second processing circuit 210b determines whether all output data, such as the first and second output data OD1 and OD2, corresponding to the received trigger IDs, such as the first and second trigger IDs TID1 and TID2, are processed by the second processing circuit 210b. Since at step 572, the second processing circuit 210b determines that all output data corresponding to the received trigger IDs are not processed by the second processing circuit 210b, the steps 552 to 570 are executed continuously to process the second output data OD2. Further, the step 572 is executed, and the second processing circuit 210b determines that all output data corresponding to the received trigger IDs are processed by the second processing circuit 210b. Thus, the second processing circuit 210b completes the generation of all the processed data, thereby completing the processing of the input image lines.

The system 100 does not employ stitching of input image lines received from the first and second image sensors 102a and 102b. Thus, the latency incurred by the system 100 as compared to the latency incurred due to stitching of image lines employed by conventional image processing systems for on-the-fly processing of each input image is reduced. Further, a quality of the first and second processed data PD1 and PD2 remains unaffected due to a difference in exposure values and difference in resolutions of the first and second image sensors 102a and 102b as the processing of the first and second input image lines IIL1 and IIL2 is based on a set of configuration parameters (i.e., the first and second sets of configuration parameters CP1 and CP2) and associated trigger IDs, such as the first and second trigger IDs TID1 and TID2. In addition, the first processing circuit 210a and the second processing circuit 210b are able to process same or different input image lines, such as the first and second input image lines IIL1 and IIL2, parallelly by way of the data exchange circuit 212 as compared to conventional processing systems that were able to process only a single input image line at a time. Thus, a processing overhead and a delay in processing of the multiple input image lines is reduced by utilizing the system 100 as compared to utilizing the conventional image processing systems.

While various embodiments of the present disclosure have been illustrated and described, it will be clear that the present disclosure is not limited to these embodiments only. Numerous modifications, changes, variations, substitutions, and equivalents will be apparent to those skilled in the art,

without departing from the spirit and scope of the present disclosure, as described in the claims.

The invention claimed is:

1. A system-on-chip (SoC), comprising:

5 first and second processing circuits, wherein the first processing circuit is configured to receive and process a first image line based on a first set of processing attributes to generate first output data, and a second image line based on a second set of processing attributes to generate second output data, and wherein the second image line is processed after the first image line is processed; and

10 a data exchange circuit coupled between the first processing circuit and the second processing circuit, wherein the data exchange circuit is configured to provide the first and second output data from the first processing circuit to the second processing circuit based on an availability of the second processing circuit to process the first and second output data, respectively, and wherein the second processing circuit is configured to parallelly process the first output data when the first processing circuit processes the second image line.

2. The SoC of claim 1, wherein the second processing circuit is further configured to process the second output data after the first output data is processed, and wherein the first and second output data are processed based on the first and second sets of processing attributes, respectively.

3. The SoC of claim 1, further comprising:

30 an arbitration circuit that is configured to receive first and second access requests and first and second sets of configuration parameters that are associated with the processing of the first and second image lines, respectively, generate first and second trigger identifiers (IDs) based on the first and second access requests, respectively, and output the first and second trigger IDs and the first and second sets of configuration parameters, respectively, wherein the first set of processing attributes includes the first trigger ID and the first set of configuration parameters, and the second set of processing attributes includes the second trigger ID and the second set of configuration parameters.

4. The SoC of claim 3, further comprising:

45 a set of cores that is coupled with the arbitration circuit, and is configured to receive the first and second image lines, generate the first and second access requests and the first and second sets of configuration parameters, and provide the first and second access requests and the first and second sets of configuration parameters, respectively, to the arbitration circuit.

50 5. The SoC of claim 4, wherein the arbitration circuit comprises:

55 an access serializer that is coupled with the set of cores, and is configured to receive the first and second access requests and the first and second sets of configuration parameters, respectively, serialize the first and second access requests, and output the serialized first and second access requests and the first and second sets of configuration parameters, respectively, wherein the access serializer serializes the first and second access requests by executing a scheduling algorithm such that when the first and second access requests are received simultaneously, the access serializer outputs the serialized first and second access requests one after the other; first and second trigger controllers that are coupled with the access serializer, and are configured to receive the serialized first and second access requests and the first and second sets of configuration parameters, respec-

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- tively, and decode the serialized first and second access requests to generate first and second trigger signals and the first and second trigger IDs, respectively, wherein the first and second trigger controllers are further configured to activate the first and second trigger signals upon decoding the serialized first and second access requests, respectively; and
- first and second configuration registers that are coupled with the first and second trigger controllers, and are configured to receive the first and second trigger signals, and receive the first and second sets of configuration parameters from the first and second trigger controllers when the first and second trigger signals are activated, respectively.
6. The SoC of claim 5, wherein the arbitration circuit further comprises:
- a broadcaster circuit that is coupled with the first and second trigger controllers, and is configured to receive the first and second trigger IDs and output the first and second trigger IDs based on an order of reception of the first and second trigger IDs, respectively; and
 - a context arbiter circuit that is coupled with the broadcaster circuit, and is configured to:
 - receive the first and second trigger IDs from the broadcaster circuit,
 - receive first and second status signals,
 - select the first and second configuration registers based on the first and second trigger IDs for receiving the first and second sets of configuration parameters therefrom, and
 - provide at least one of the first and second sets of configuration parameters to the first processing circuit when the first status signal is activated, and at least one of the first and second sets of configuration parameters to the second processing circuit when the second status signal is activated.
7. The SoC of claim 3, wherein the first processing circuit comprises:
- a first receiver that is coupled with the arbitration circuit, and is configured to receive the first and second trigger IDs and generate a first reception signal that is indicative of a reception of at least one of the first and second trigger IDs by the first receiver; and
 - a first kernel that is coupled with the first receiver and the arbitration circuit, and is configured to:
 - (i) receive the first reception signal and at least one of the first and second sets of configuration parameters based on a first status signal,
 - (ii) receive the first and second image lines,
 - (iii) process, based on the first reception signal, at least one of the first and second image lines to generate at least one of the first and second output data, respectively, and
 - (iv) generate and provide the first status signal to the arbitration circuit, wherein the first kernel is further configured to activate the first status signal for receiving at least one of the first and second sets of configuration parameters, and deactivate the first status signal when the first kernel is processing at least one of the first and second image lines.
8. The SoC of claim 3, wherein the second processing circuit comprises:
- a second receiver that is coupled with the arbitration circuit, and is configured to receive the first and second trigger IDs and generate a second reception signal that is indicative of a reception of at least one of the first and second trigger IDs by the second receiver; and

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- a second kernel that is coupled with the second receiver, the arbitration circuit, and the data exchange circuit, and is configured to:
 - (i) receive the second reception signal and at least one of the first and second sets of configuration parameters based on a second status signal,
 - (ii) receive the first and second output data from the data exchange circuit,
 - (iii) process, based on the second reception signal, at least one of the first and second output data to generate at least one of first and second processed data, respectively, and
 - (iv) generate and provide the second status signal to the arbitration circuit, wherein the second kernel is further configured to activate the second status signal for receiving at least one of the first and second sets of configuration parameters, and deactivate the second status signal when the second kernel is processing at least one of the first and second output data.
9. The SoC of claim 8, further comprising:
- a main memory that is coupled with the second processing circuit, and is configured to receive the first and second image lines and the first and second processed data, and store the first and second image lines and the first and second processed data, respectively.
10. The SoC of claim 1, wherein the first output data comprises first and second data segments, and wherein the data exchange circuit is further configured to provide the first data segment received from the first processing circuit to the second processing circuit when the second processing circuit is available to receive the first data segment such that the second processing circuit processes the first data segment and the first processing circuit parallelly generates the second data segment.
11. The SoC of claim 1, wherein the second processing circuit is further configured to generate an indication signal and provide the indication signal to the data exchange circuit to indicate the availability of the second processing circuit for processing at least one of the first and second output data.
12. The SoC of claim 1, wherein the SoC is coupled with external first and second image sensors, wherein the first and second image lines are captured by the first and second image sensors, respectively, and wherein the first and second image sensors have different resolutions and different frame rates.
13. A method for processing a plurality of image lines, the method comprising:
- processing, by a first processing circuit of a system-on-chip (SoC), a first image line of the plurality of image lines based on a first set of processing attributes to generate first output data, and a second image line of the plurality of image lines based on a second set of processing attributes to generate second output data, wherein the second image line is processed after the first image line is processed;
 - providing, by a data exchange circuit of the SoC, the first and second output data from the first processing circuit to a second processing circuit of the SoC based on an availability of the second processing circuit to process the first and second output data, respectively; and
 - processing, by the second processing circuit, the first output data parallelly when the second image line is being processed by the first processing circuit.
14. The method of claim 13, further comprising:
- processing, by the second processing circuit, the second output data after the first output data is processed,

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wherein the first and second output data are processed based on the first and second sets of processing attributes, respectively.

15. The method of claim **14**, further comprising:
generating, by the first processing circuit, a first status signal, wherein the first status signal is activated based on an availability of the first processing circuit to receive at least one of the first and second sets of processing attributes, and the first status signal is deactivated when at least one of the first and second image lines are being processed by the first processing circuit; and

generating, by the second processing circuit, a second status signal, wherein the second status signal is activated based on an availability of the second processing circuit to receive at least one of the first and second sets of processing attributes, and the second status signal is deactivated when at least one of the first and second output data are being processed by the second processing circuit.

16. The method of claim **13**, further comprising:
generating, by an arbitration circuit of the SoC, first and second trigger identifiers (IDs) based on first and second access requests and first and second sets of configuration parameters that are associated with the processing of the first and second image lines, respectively, wherein the first set of processing attributes includes the first trigger ID and the first set of configuration parameters, and the second set of processing attributes includes the second trigger ID and the second set of configuration parameters.

17. The method of claim **16**, further comprising:
serializing, by an access serializer of the arbitration circuit, the first and second access requests to output the serialized first and second access requests, wherein the first and second access requests are serialized by executing a scheduling algorithm such that when the first and second access requests are received simultaneously, the serialized first and second access requests are outputted one after the other by the access serializer;

receiving the serialized first and second access requests and the first and second sets of configuration param-

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eters, by first and second trigger controllers of the arbitration circuit from the access serializer, respectively;

decoding the serialized first and second access requests, by the first and second trigger controllers to generate first and second trigger signals and the first and second trigger IDs, respectively, wherein the first and second trigger signals are activated upon decoding the serialized first and second access requests, respectively; and outputting, by a broadcaster circuit of the arbitration circuit, the first and second trigger IDs based on an order of reception of the first and second trigger IDs by the broadcaster circuit.

18. The method of claim **16**, further comprising:
receiving, by a context arbiter circuit of the arbitration circuit, the first and second trigger IDs and first and second status signals;

selecting, by the context arbiter circuit based on the first and second trigger IDs, first and second configuration registers of the arbitration circuit to receive the first and second sets of configuration parameters therefrom; and providing, by the context arbiter circuit, at least one of the first and second sets of configuration parameters to the first processing circuit when the first status signal is activated, and at least one of the first and second sets of configuration parameters to the second processing circuit when the second status signal is activated.

19. The method of claim **13**, further comprising:
generating, by the second processing circuit, an indication signal; and

providing, by the second processing circuit to the data exchange circuit, the indication signal to indicate the availability of the second processing circuit for processing at least one of the first and second output data.

20. The method of claim **13**, wherein the first output data comprises first and second data segments, and wherein the first data segment is provided from the first processing circuit to the second processing circuit by the data exchange circuit such that the first data segment is processed by the second processing circuit and the second data segment is parallelly generated by the first processing circuit.

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